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Design and Construction of a 0.75KVA Inverter Power Supply for Nigerian Homes and Offices

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ABSTRACT

Over the years, there have been a gradual increase in the electricity generation capacity of Nigeria, with more gas power plants installed between 1999-2003 to augment power supply from the existing hydro and thermal power plants installed in the 1970s but despite gradual increase in Mega Watts (MW) of electric power generated, Nigerian electricity consumers continue to experience epileptic and unreliable power supply distribution. As at today, the power distribution companies referred to as the DISCOs supply epileptic or skeletal power to their customers which they termed 'load shading'. This term explains a situation whereby a power consumer or customer can obtain a power ration for some hours in the day and do not have power remaining hours in the day. Because of this, many consumers depend on generating sets as alternative source of power. This is inefficient and costly to maintain. Today it is possible to introduce the electric power inverter which converts battery DC voltage to AC voltage. Inside the inverter can be coupled an electric charging system which can charge the battery when there is power supply from utility power source. When this power source fails, the battery in turn supplies the inverter with DC which is being converted to A.C sometimes; the inverter can also be connected to renewable energy source like solar, wind etc. These sources ensures an all round supply of DC for the inverter. Renewable energy can be particularly suitable for developing countries such as Nigeria where public power supply is totally unreliable. In response to the yearning of the majority of Nigerians for a steady power supply, this research paper tries to contribute in a little way by designing and constructing a 0.75KVA inverter to power homes and offices. The paper starts by defining what an inverter is, reviewed similar past works in literature, and it explained the principles of operation and components used with its circuit diagram. The completed work was tested and met its design specifications.

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KEYWORDS: *VSI, inverter, transformer, resistor, power consumers, load shading, oscillator, current, voltage, source, synchronous, solar, piezoelectric, AC, DC, battery, MOSFET, SCR, VSI, CSI, terminal, GENCO, DISCO, TCN*

INTRODUCTION

Recently, public power supply situation in Nigeria has worsened. It has become a very big challenge for customers that use energy at homes, offices and even in the industry. Nigerian privatization scheme as was carried out in 2015 by the then Dr. Good luck Jonathan administration was fraught with a lot of technical ambiguities and inefficiencies. The power is generated by the generating company (GENCO), and thereafter transmitted to the Distribution Companies (DISCOs) by the Transmission Company of Nigeria (TCN).

The DISCOs in turn steps down and distribute/supply power to consumers or customers at homes, offices and factories. The major challenge is that the DISCOs do not want to buy the whole energy allotted to them by the GENCO for onward distribution to their customers. The DISCOs will prefer to buy a fraction of the allotted energy (let's say 100MW instead of 500MW allotted to them by the GENCO) and then ration this to millions of customers in different states of the country. The rationing of this meagre fraction of allotted energy is what the DISCOs termed 'load shading'. DISCOs do 'load shading' to maximize profitability at the expense of their unmetered customers. Load shading results to irregular or erratic power supply or rationing to customers where an average customer may not get power up to 12 hours in a day. Most of these customers spend a fortune to provide an alternative power supply using generating sets.

An inverter can come to the rescue in this situation by backing up the limited energy supplied by the DISCOs to its battery and then allow the user to use its battery energy to provide power for the remaining hours of the day.

An inverter is a device that changes DC power into AC power. The inversion process can be achieved with the help of transistors, SCR and tunnel dividers etc. For low and medium outputs, transistorized inverters are suitable but for high power output SCR inverters are essential. For very low voltage and high current requirement, tunnel diode inverters are used. Inverters are classified broadly as either voltage source inverter (VSI) or current source inverter (CSI).

In VSI input to the inverter is a constant DC voltage. This is usually obtained by connecting at the output source, which is usually obtained by using a large inductor in series with the voltage source at the input.

From the late nineteenth century through the middle of the twentieth century DC to AC power conversion was accomplished using rotary converters or motor – generator sets (M-G) .in the early twentieth century, vacuum tube began to be used as switches in inverters circuits. The most widely used types of tube were the thyretron.

The origin of electromechanical inverters explains the source of the term inverter. Early AC to DC converters used as induction or synchronous AC motor direct connected to a generator (dynamo) so that the generators commutator revised its connection at exactly the right moments to produce DC. A later development is the synchronous converter, in which the generator and motor windings are combined into one armature, with slip rings at one end and a commutator at the other end only one field frame. The result with either is AC – in, DC-out with an M-G sets the DC can be considered to be separately generated from the AC, with a synchronous converter, in a certain sense can be considered to be mechanically rectified AC" given the right auxiliary and control equipment an M-G sets or rotary converter can be run backward converting DC to AC. Hence an inverter is an inverted converter.

A. Problem Statement

Public power supply in Nigeria is a big challenge to millions of electricity consumers. The Power Distribution Companies (DISCOs) ration or share power, rotationally, distributing an average of 6-12 hours of power daily to customers. This is inadequate to meet any basic power requirement of a consumer or customer. The inverter system can be used as an alternative in homes, offices and factories to ameliorate the epileptic public power supply. Similarly, the inverter system is being faced with some challenges which this paper work is going to address such as:

1. The problem of switching from DC to AC.
2. The problem of battery at under/over charge.
3. The problem of overload.
4. The problem of the wiring and circuit and cable size.

B. Aim of the Paper

The aim of this research paper is to construct and implement a 0.75 KVA Inverter System with overload control mechanism

C. Objective of the Paper

The main objective of this paper is to have a device which ensures that there is an alternative source in case of any form of power failure from utility power supply. An inverter as earlier said, is an electrical or electro-mechanical device that convert direct current (DC) to alternating current (AC) the resulting AC can be at any required voltage and frequency with the use of appropriate transformer, switching and control circuit.

RELATED WORKS

Authors in [1] designed and implemented a modified sine wave 0.75 kVA inverter for the viewing center in Iloro community, Ondo State, Nigeria to provide backup alternative source of electric power to the community. The inverter design applied three units or stages namely-oscillation and driver amplifier units, power MOSFET Amplifier unit and centre-tapped Isolated step-up transformer unit. The results obtained from the load test show that the higher the load, the higher the input direct current power drawn from the battery. According to the authors, the average efficiency of the inverter was about 70 %.

Author in [2] designed and developed a 600 VA DC-AC inverter system to provide alternative backup power supply for a community in Rwanda. The result from the author showed that the inverter worked very well in meeting the objective of the design.

THE PROPOSED SYSTEM

The architecture and system analysis of the proposed system is described in this section.

A. System Overview

This research paper was done to arrive at a construction that ensures maximum efficiency at a reduced consumption of energy. Here, readily available components such as Ne555 timer, CD4013 flip flop IC and the IRF 3205 field effect transistors were used. Finally, the transformer was locally fabricated by buying a burnt 2000W transformer, loosed it and got the lamination. New coils were purchased locally for the transformer windings.

B. System Design

The system design stage involves the series of object modification and manipulations until the desired results of the small prototype are evolved. It is this manipulation that gives rise to the newly evolved vehicle fault detection system. The main feature guides the simulation of this application and such features include:-

C. Block diagram of an Inverter System

The block diagram of an inverter system is depicted in Fig.1.

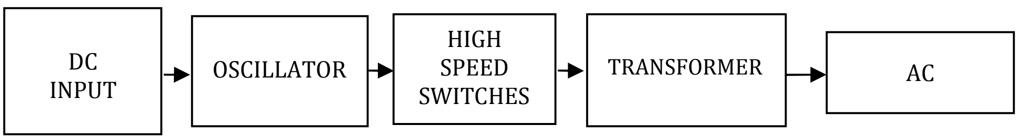

Fig.1. the block diagram of an inverter system

D. Circuit Description

For proper and comprehensive explanation, the circuit can be divided into the following three sub-circuits:-

- Oscillator section
- High speed switching section
- Transformer section

IMPLEMENTATION

This section describes the implementation stage of this paper.

A. Oscillator Section

An oscillator is an electronic circuit that produces a repetitive electronic signal, often a sine wave or square wave. There are three main types of electronic oscillator.

1. The harmonic oscillator
2. Relaxation oscillator

The harmonic or linear oscillator produce a sinusoidal output the basic form of a harmonic oscillator is an electronic amplifier with the output attached to an electronic filter, in a feedback loop. When the supply to the input of the amplifier is first switched ON, the amplifiers output consists of only noise. The noise travel round the loop being filtered and re-amplified until the signal resembles the desires signal. A piezoelectric crystal may take the place of the filter to stabilize the frequency of oscillation, resulting in a crystal oscillator. The relaxation oscillator is often used to produce a non-sinusoidal output, such as a square waves or saw tooth. The oscillator contains a non-linear component such as a transistor that periodically discharges the energy stored in a capacitor or inductor, causing abrupt changes in the output waveform. Square wave relaxation oscillator can be used to provide the clock signal for sequential logic circuit such as timers and counters, although crystal oscillators are often preferred for their greater stability.

Triangle wave or saw tooth oscillator are used in the time base circuits that generate the horizontal deflection signal for cathode ray tubes in analogue oscilloscope and television sets. In function generators, this triangular wave may then be further shaped into a close approximation of a sine wave. Other types of relaxation oscillators include the multivibrator and rotary travelling wave oscillator. The oscillator in this circuit is a multivibrator which produces a square wave with a frequency of about 120 Hz. This value is derived from the formula:

$$f=\frac{1}{0.693}*(RI*2R2)\ CI$$

From this formula it is clear to say that the frequency of the oscillating waveform is totally dependent on the values of R1, R2 and C1 connected in the circuit.

B. High Speed Switch Section

This section comprises field effect transistors connected in parallel along two channels. They are connected three in each section to increase the amount of current they can conduct thereby increasing the power of the entire system. Each channel functions as a switch complementary to the other i.e.; while one channel is ON the other is OFF and vice versa courtesy of the oscillator connected to both channels. Fig.2 depicts the illustration of how the FET functions as a switch.

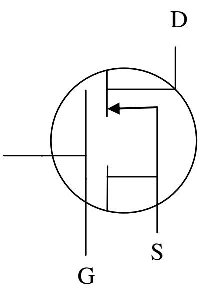

Fig.2. Symbol of a FET

By applying a suitable drive voltage to the gate of any FET, the resistance of the drain-source channel can be varied from an "OFF-resistance" of many hundreds of kilo ohms, effectively an open circuit, to an "ON-resistance" of less than 1ohm, effectively a short circuit.

We can also drive the MOSFET to turn "ON" fast or slow, or to pass high current or low current. This ability to turn the power MOSFET "ON" and "OFF" allows the device to be used as a very efficient switch with switching speed much faster than standard bipolar junction transistor.

An example using MOSFET as a switch is shown in Fig.3.

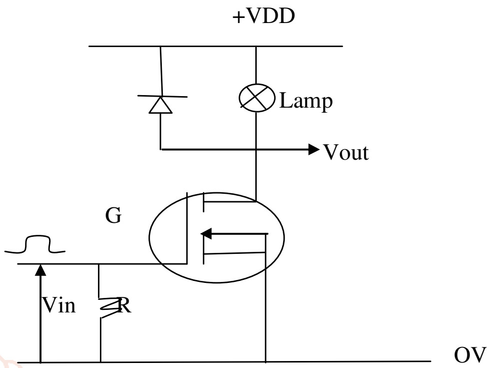

Fig.3. Using MOSFET as a switch

In this circuit arrangement, an enhancement mode N-channel MOSFET is being used to switch lamp ON and OFF The gate input voltage Vas is taken to an appropriate position level to turn the device and the lamp either fully ON (VGs = +ve) or a zero voltage level to turn the device fully OFF (VGs = 0).

If the resistive load of the lamp was to be replaced by an inductive load such as a coil or solenoid, a "flywheel" diode would be required in parallel with the load to protect the MOSFET from any back–emf.

C. Transformer Section

A transformer is a device used in stepping up or down of voltage or current. The transformer used in this circuit is a 12/220V step up transformer.

Below are the steps taken to arrive at this transformer rating (12/220V):-

1. We got proper E.I lamination and laminating core.
2. We got the appropriate standard wire gauge for the winding in the primary and secondary we used 16swg for primary winding and 22swg for secondary winding.
3. From research, we found out that the secondary winding varies in number of turns from 500 to 1500 turns but we choose 1000 turns. It is very important to note that as the number of turn's increases, the efficiency of the transformer also increases so it is safer to go for higher number of turns.
4. Having known these three parameters; primary voltage E1 (12V), secondary voltage E2 (220V), secondary winding N2 (1000).

We now calculated the primary winding from the formula:

$$\frac{\mathrm{E1}}{\mathrm{E2}}=\frac{N1}{N2}$$

From this formula, we derived N1= 54 times.

5. At this point we got our laminating core and started winding the primary coil round the core. After winding

54 turns, the terminal was brought out and sent in again to wind another 54 turns, now we have three terminals for the primary winding and the middle terminal is known as the centre tap.

6. The primary winding is now properly insulated and the winding of the secondary now begins upon this insulation, we continue the winding until we got 1000 turns, the proper insulation was carried out to prevent every form of leakage.
7. The E1 lamination are now inserted into the core and properly fitted and screwed to avoid air losses.
8. Testing was done by connecting the secondary terminals to 220v AC and reading the primary terminals with a multimeter, we measured 12v across the first and second terminals with a multimeter and also across the second and third terminals.

IMPLEMENTATION

This section describes the implementation stage of this paper.

A. Principle of Operation

In a simple inverter circuit, DC power is connected to a transformer through a centre tap of the primary windings. A switch is rapidly switched back and forth to allow current flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in secondary circuit.

The oscillator used in this circuit is a bi-stable multivibrator which produces a flip flop square wave signal. It has two outputs terminal from which a complementary square wave is produced as shown in Fig.4.

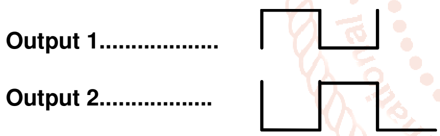

Fig.4: Square wave produced by an oscillator

These two output goes as input to two channels of high speed electronic switches (field effect transistors.) the two switch channels is turned ON and OFF by the signal coming from the oscillator thereby making only one of the channels to go ON at a time. The operation of this circuit can be detailed in steps as seen below:

1. Power is turned ON by pressing a switch which connects the oscillator VCC to 12v DC supply coming from a battery.
2. The oscillator produces a complementary square wave at each of its output terminals.
3. The square wave which is connected to each of two field effect transistor channels switch it ON and OFF at a frequency of 50Hz as specified in the oscillator. That is to say, one channel is ON at a time when the other is OFF vice versa.
4. The drain terminal of field effect transistor connected to the primary of a step up transformer also switches the transformer ON and OFF thereby alternating the voltage at that terminal between 12v and 0v.
5. This primary terminal of transformer is center-tapped and common terminal is connected to 12v therefore potential difference is hereby alternated between the two coil at same frequency mentioned above.
6. Because the transformer is a 12v/220v step up type a sinusoidal waveform of 220v will be induced in its secondary terminals
7. These two terminals can be connected at an output socket to supply a 220v AC.

B. Steps involved in Building the Circuit

1. All the needed components were sourced and acquired. The components sourced ranges from resistors to integrated circuits.
2. Also sourced include a 60W soldering iron, soldering lead, multimeter and Vero board.
3. The components were placed on the Vero board and soldered one after the other.
4. Open circuit continuity test were made to eliminate all forms of error.
5. The circuit was tested when connected and not connected, and finally coupled in an IP65 casing.

C. How the Vero board was prepared

This work was completed by using a Vero board to assemble the above mentioned electronic components. The processes described below were to prepare the Vero board. Grab a very sharp craft knife and a ruler on the track side of the board, count 40 complete holes along a track, then place the ruler perpendicular to the tracks on the next hole. Now turn the board over, and repeated the operation in exactly the same place on the component side. Pick up the board and snap it with both hands, keeping your finger close to the score mark on either side. It should break evenly, leaving you with two rectangular pieces. Also count 39 tracks from the edge , then lay your ruler along the 40th track and score through the holes on the track. Do the same on the other side, then snap. If all went well, we should now have a piece of Vero board of correct size 39 tracks by 40 holes.

D. Inspecting the Tracks

Occasionally, a piece of Vero board will have defects such as small splashes of copper bridging adjacent tracks. Inspect the board carefully t make sure there are no bridges. If there is run your knife between tracks in order to cut it.

E. Soldering

Soldering is the process of making a sound electrical and mechanical joint between certain metals by joining them with a soft solder. This is a low temperature melting point alloy of lead and thin. The joint is heated to the correct temperature by soldering iron.

Good soldering is a skill that is learnt by practice. The most important point in soldering is that both parts of the joints to be made must be at the same temperature. The solder will flow evenly and make good electrical and mechanical joint only if both parts of the joint are at an equal high temperature.

F. Packaging of the Inverter

Figs 5 and 6 show the packaged finished product of the inverter using sealed metal casing to protect it from dust, water and weather conditions.

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G. Components Used

The components used in the research project include: -

1. Transistors (MOSFET, JFET, FET)
2. Resistors

3. Capacitors
4. Transformer (12/220V step up transformer)
5. Diodes
6. 555 timer IC
7. Incandescent lamp
8. CD 4013 Flip flop IC
9. 12 V battery

Fig.5. Inner view of the open casing unit of the completed inverter circuit

Fig.6. Top view of the sealed metal casing unit of the completed inverter circuit

M1-M6 = 1RF 3205 field effect transistor
T1=1 (12-0-12) V to 240v step up centre tapped transformer
S1= 220v incandescent lamp
Vcc = 12v Battery

H. Components Identification

The components used and their corresponding values are as follow:-

R1= 1.5 kilo ohm Resistor
R2= 127 kilo ohm Resistor
R3= 100 ohm Resistor
R4-129 = 47 ohm Resistor
R10 = 220 ohm Resistor
C1, and C2 = 100nf capacitor
U1= NE555 timer IC

I. Testing

After the construction, the circuit was properly analyzed and short circuit and open circuits were all connected. The circuit is then powered with a voltage supply.

RESULT AND DISCUSSION

The circuit was able to retain the power supply for several hours and charged the connected lithium battery. The battery was later used to provide backup power supply after the voltage supply was removed.

CONCLUSION

Generally, power supply simply refers to the generation and supply of electrical and electronic load. Devices that fall into this category include mechanical generator convert one form of energy into electrical energy. In particular, an inverter is an electrical device that converts direct current (DC) to alternating current (AC) the converted AC can be at any require voltage and frequency with the use of appropriate transformers, switching, and control circuits. It is essentially the opposite of rectifier. In this paper, DC supply is gotten from either a battery or solar panel and converted into AC supply by an electric inverter. The solar energy is gotten from the sun, stored in a battery and also used to power the inverter. This energy from the sun is solar energy and is converted into direct electrical current by the solar panel. On the other hand, the battery can be changed with a converter which connects to the utility power supply; the direct current is in turn converted into alternating current which can be used to power almost every electrical appliance found in our home and offices. Energy stored in the inverter can be used to provide backup power for the rest of the day when the DISCOs ration its limited energy.

RECOMMENDATIONS

[1] The inverter system can be upgraded to a higher capacity voltage inverter (>1.0KVA) to provide backup for larger loads at home, offices and factories.

[2] The inverter should not be overloaded with much higher loads so as to elongate its life span.

[3] Users or consumers at home, offices and factories should procure this type of inverter systems to help ameliorate the public power supply situations in Nigeria.